AD 404 231

63-3-4

UNCLASSIFIED

DETECTION and DESIGNATION

~~MONOGRAPH NUMBER~~ 2

Atmospheric Property Approximation

COMMANDING GENERAL
U. S. ARMY MISSILE COMMAND
ATTN, AMSMI-RNR
REDSTONE ARSENAL, AL BAMA

REQUIREMENTS and PLANS DIVISION

Research And Development Operations, ARGMA

1.60

UNCLASSIFIED

28 September 1960

MONOGRAPH NR. 2

ATMOSPHERIC PROPERTY APPROXIMATION

~~WRITTEN~~ BY:

ROBERT H. C. AU
Capt., ORDC

ORLANDO E. KATTER, JR.

E. J. LITTLE

and

WILLIAM J. SCHULTIS
Lieutenant, ORDC

APPROVED BY:

WILLIAM J. LINDBERG
Ch, Detection & Designation Section
Experimental Programs Branch
Requirements & Plans Division
Research & Development Operations

DAVID D. WOODBRIDGE
Ch, Experimental Programs Branch
Requirements & Plans Division
Research & Development Operations

INTRODUCTION:

~~This monograph is concerned with~~ two properties of the earth's atmosphere which are pertinent to the description of the phenomenon associated with the reentry of a hypersonic body are discussed. These two properties, density and pressure, are functions of the geometric altitude and vary in a manner which can be approximated by exponential relations. Specific relations for the properties are given for altitudes up to 350 Kft.

Since the altitude regime was considered in several increments and the most recent data was utilized i.e., The 1959 Model ARDC Atmosphere, the approximations provide a reasonably accurate determination of the atmospheric property values. In addition, the relations are in a form amenable to incorporation into expressions of motion and aerodynamic heating parameters.

ATMOSPHERIC DENSITY APPROXIMATION:

In the initial simplified analysis of the motion and heating characteristics of bodies reentering at hypersonic velocities(1), Allen and Eggers approximated the density property of the earth's atmosphere. By using the data then available(2,3), a relation of the following form was derived:

$$\rho = \rho_c \, e^{-\frac{h}{\eta}} \qquad (1)$$

where for 20 Kft $<$ h $<$ 180 Kft

$$\rho_c = 3.4 \times 10^{-3} \text{ slugs/ft}^3$$

$$\eta = 22 \text{ Kft}$$

The above density relation is plotted in Figure 1 along with the most recent atmospheric data(4). It can be seen that the agreement in the lower altitude regime is excellent and, even throughout the entire range, it provides an average value of the density.

Recent interest in higher altitudes, however, has necessitated a more accurate approximation for use in the analysis of reentry phenomena. A relation of the above form is to be preferred; accordingly, the 1959 ARDC Model atmosphere has been approximated by three specific relations, applicable in respective altitude regions where the parameters ρ_c and η assume the following values:

a. Region I, Figs. 2, 3

50 Kft $<$ h $<$ 135 Kft

$\rho_c = 3.6 \times 10^{-3}$

$\eta = 21.44$

b. Region II, Figs. 2, 4

135 Kft $<$ h $<$ 240 Kft

$\rho_c = 1.07 \times 10^{-3}$

$\eta = 26.48$

c. Region III, Figs. 2, 5

240 Kft $< h <$ 350 Kft

$\rho_c = 1.15 \times 10^{-1}$

$\eta = 17.45$

The approximations, it is hoped, will be useful in obtaining rapid estimations of the atmospheric density.

ATMOSPHERIC PRESSURE APPROXIMATION:

An attempt, similar to the previous section regarding density, for the best estimate of atmospheric pressure is presented here. The same reference, ARDC 1959, has been used and the two lower altitude regions are the same as those used in the density case. However, it seemed necessary to write separate pressure equations in the altitude range of 240 Kft to 300 Kft. Region three covers 240 Kft to 300 Kft and region four covers 300 Kft to 350 Kft.

The general equation for atmospheric pressure is as follows:

$$p = ke^{-mh} \qquad (2)$$

where k is lbf/ft^2

m is Kft^{-1}

The four specific relations, applicable in respective altitude regions, are given below where the parameters k and m assume the following values:

a. Region I, Figs. 1, 2

25 Kft $< h <$ 135 Kft

$k = 2.4376 \times 10^3$

$m = 4.528 \times 10^{-2}$

b. Region II, Figs. 1, 3

135 Kft $< h <$ 240 Kft

$k = 1.3186 \times 10^3$

$m = 4.076 \times 10^{-2}$

c. Region III, Figs. 1, 4

$$240 \text{ Kft} < h < 300 \text{ Kft}$$

$$k = 1.15920 \times 10^5$$

$$m = 5.94 \times 10^{-2}$$

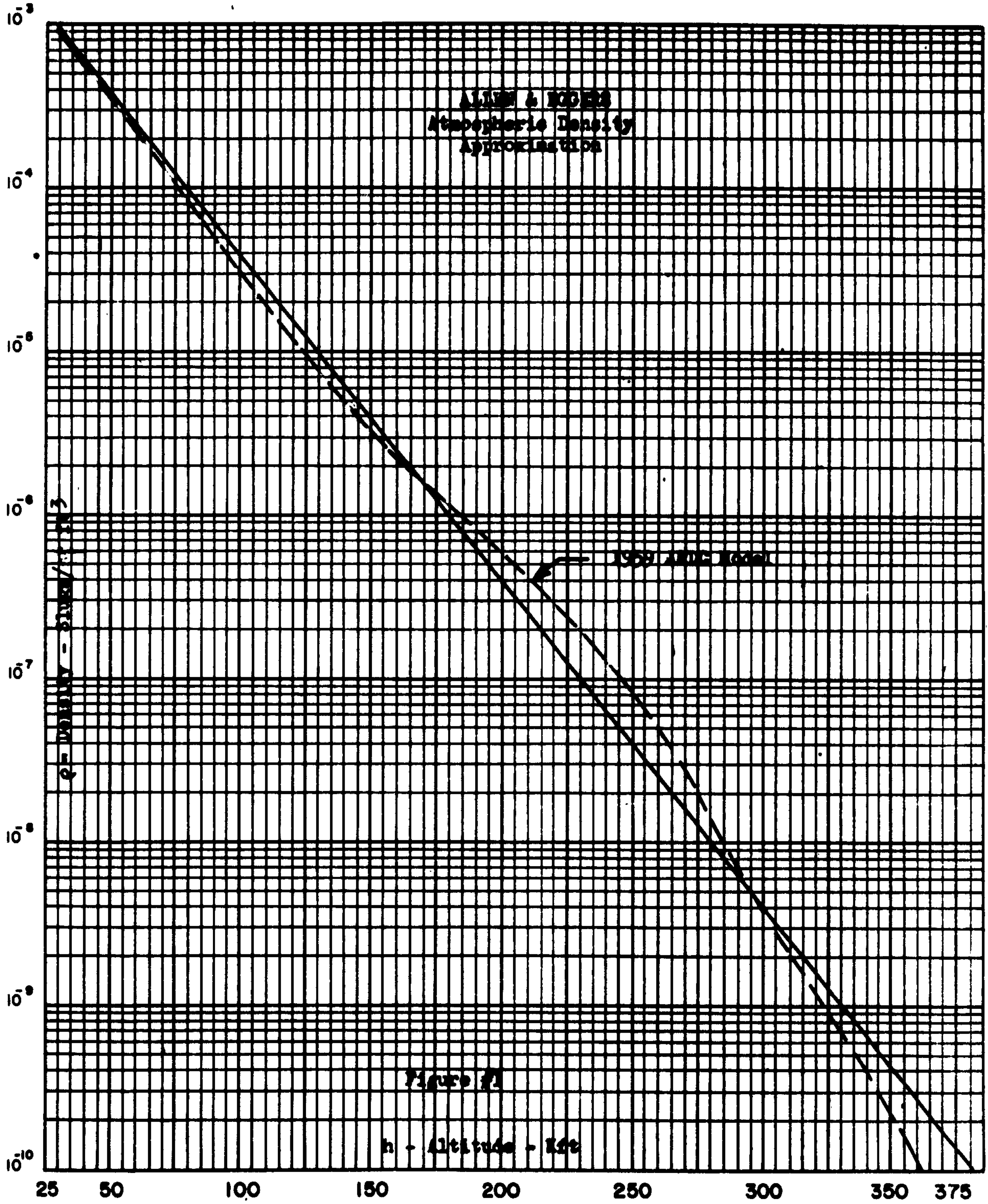
d. Region IV, Figs. 1, 5

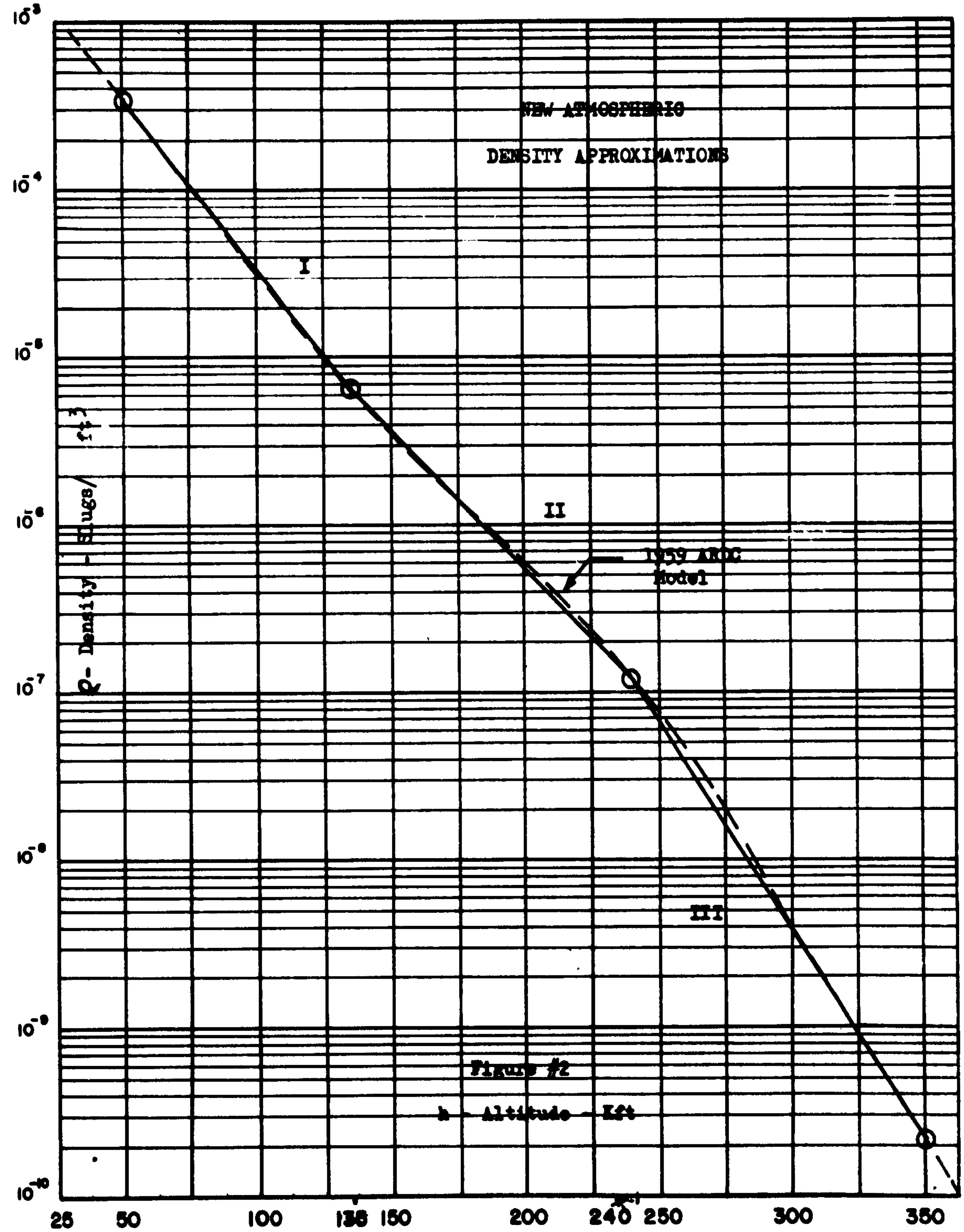
$$300 \text{ Kft} < h < 350 \text{ Kft}$$

$$k = 1.24717 \times 10^4$$

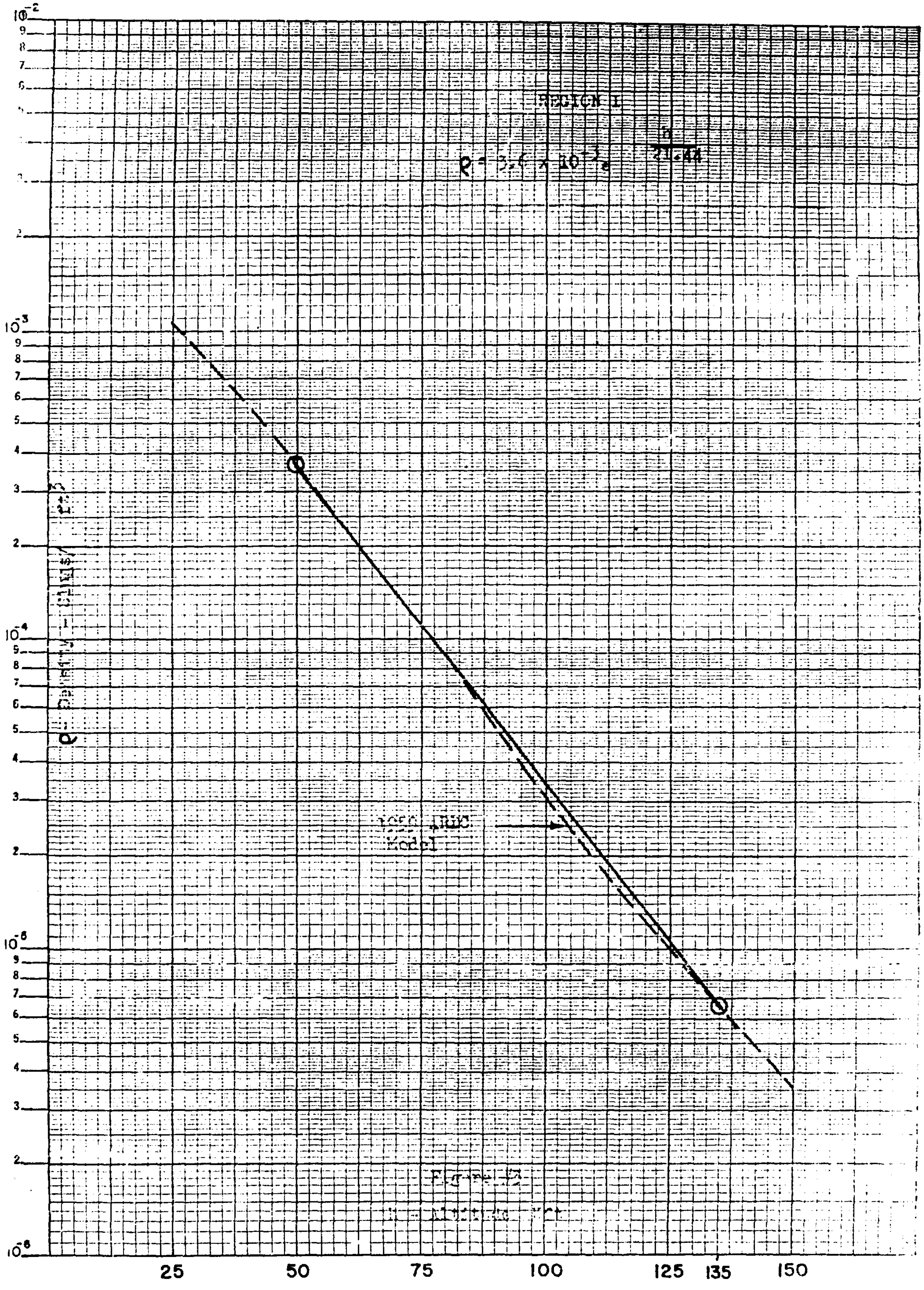
$$m = 5.196 \times 10^{-2}$$

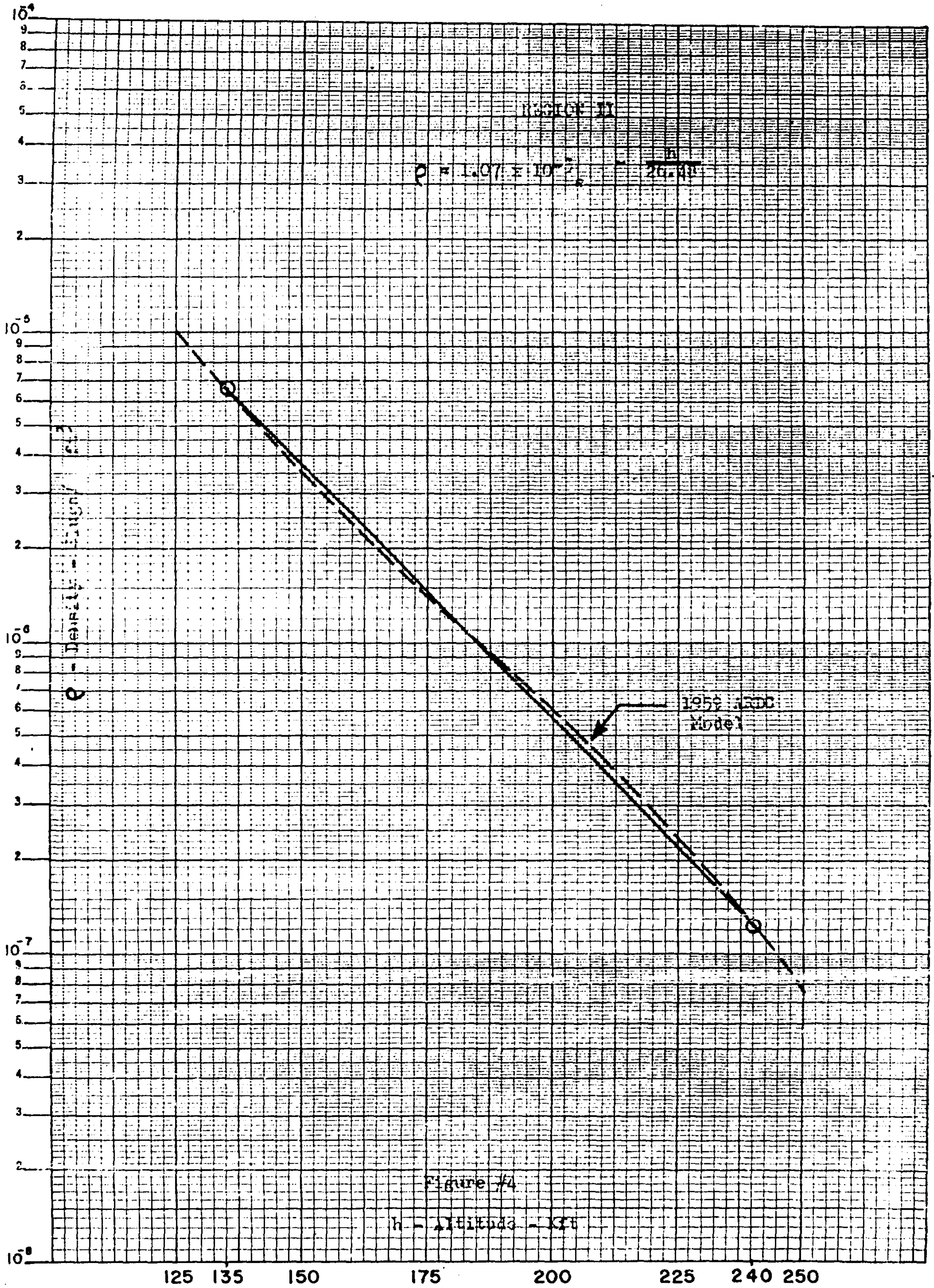
Of course, the equations are not meant to give exact results. However, it is hoped that they represent approximations close enough to be useful as rapid calculations of the atmospheric pressure within the prescribed altitudes.


10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
Figure #1
h - Altitude - Kft
25
50
100
150
200
250
300
350
375



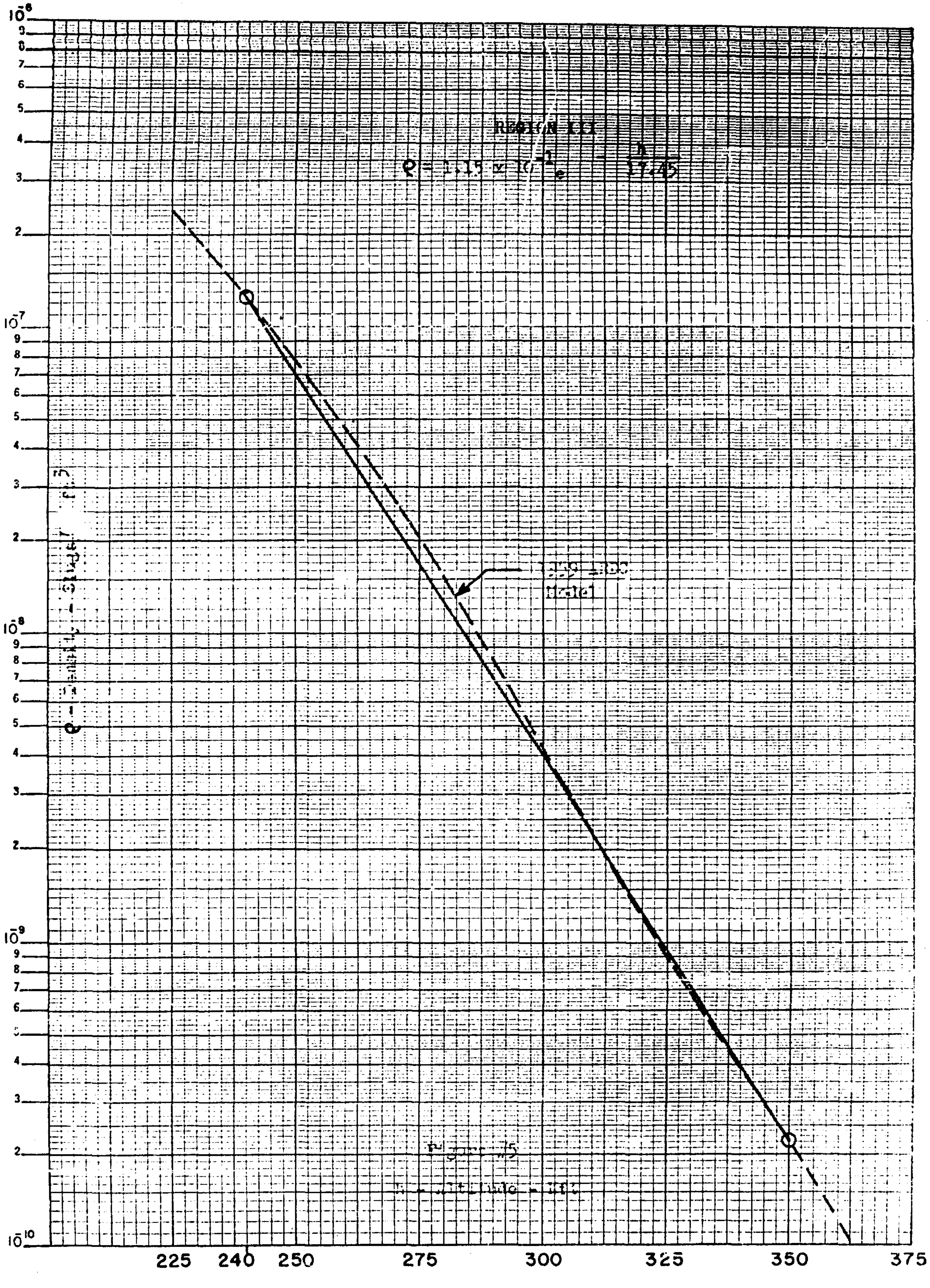
NEW ATMOSPHERIC
DENSITY APPROXIMATIONS
I
II
III
1959 ARDC
Model
Figure #2
h - Altitude - Kft
ρ - Density - Slugs/ft^3
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
25
50
100
135
150
200
240
250
300
350


REGION I
Model
25
50
75
100
125
135
150

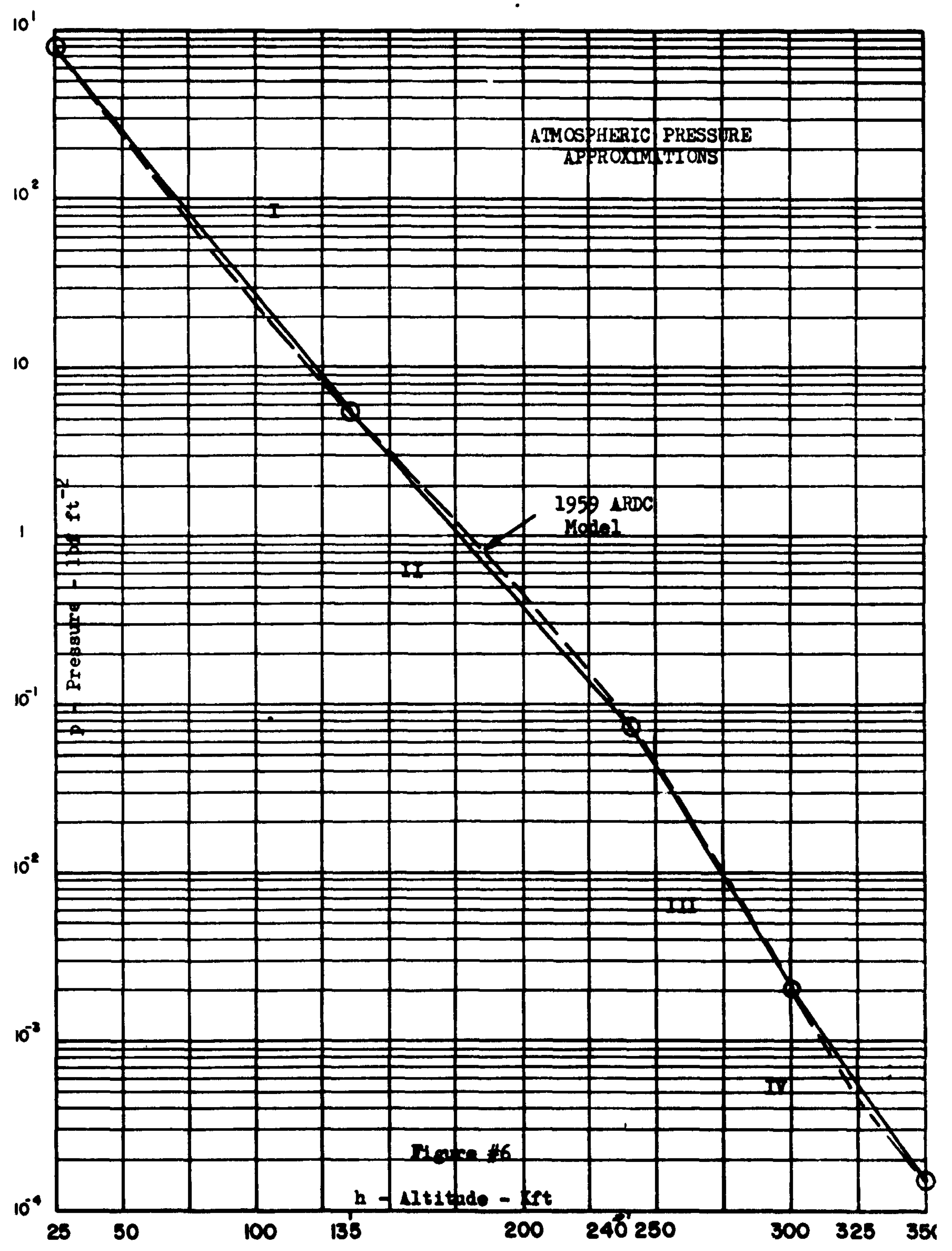


REGION II
1959 ARDC Model
ρ - Density
h - Altitude - Kft
125 135 150 175 200 225 240 250
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}

Figure #4

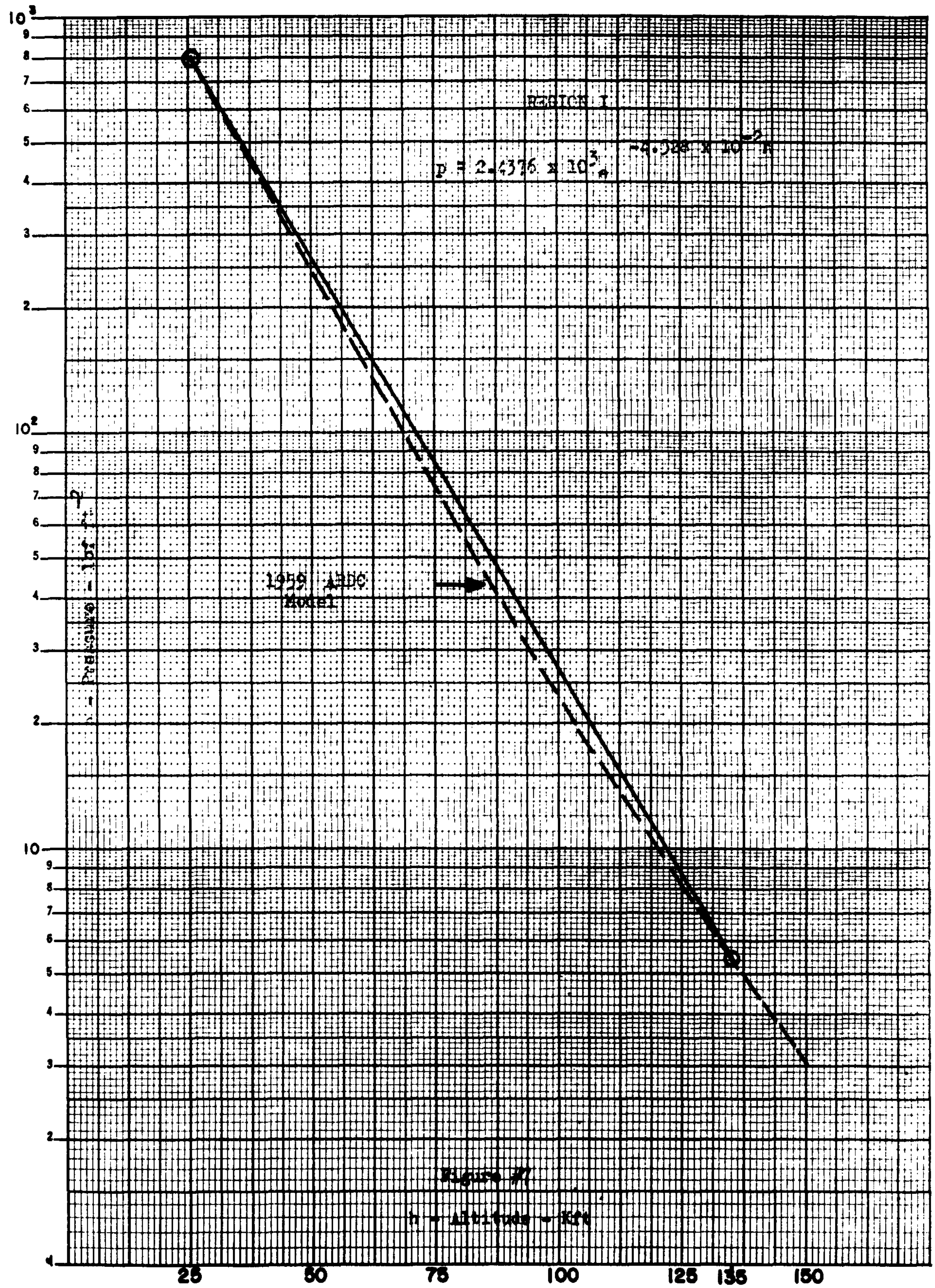


REGION III
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
225
240
250
275
300
325
350
375



ATMOSPHERIC PRESSURE
APPROXIMATIONS
1959 ARDC
Model
I
II
III
IV
p - Pressure - lbf ft^{-2}
h - Altitude - Kft
10^1
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
25
50
100
135
200
240
250
300
325

Figure #6



REGION I
p = 2.4376 x 10^3
1959 ARDC
Model
Figure #7
h - Altitude - Kft

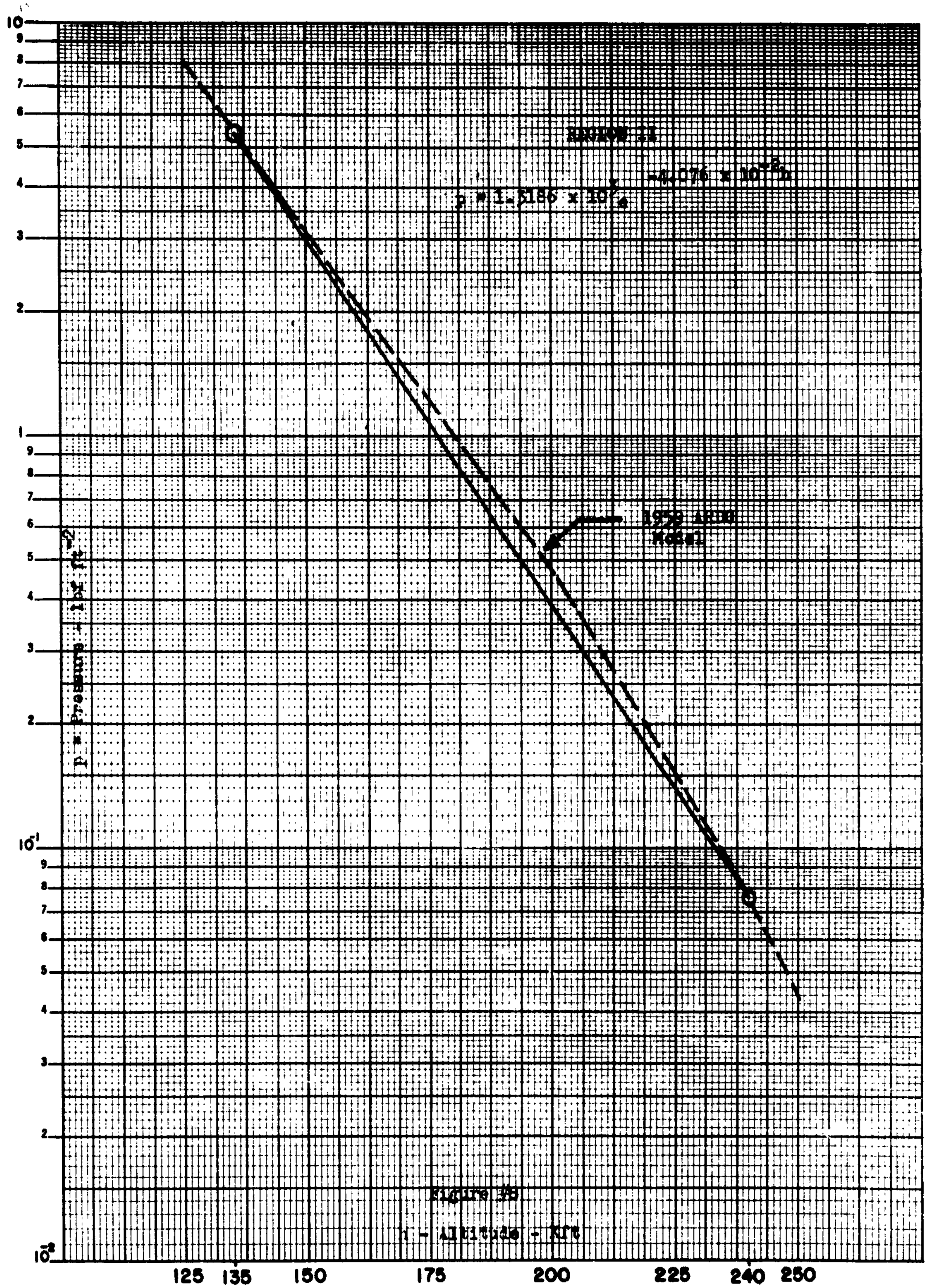

REGION II
p = 1.5186 x 10^7 e^(-4.076 x 10^-2 h)
1959 ARDC Model
p = Pressure - lbf ft^-2
h - Altitude - Kft
10
1
10^-1
10^-2
125
135
150
175
200
225
240
250

Figure #8

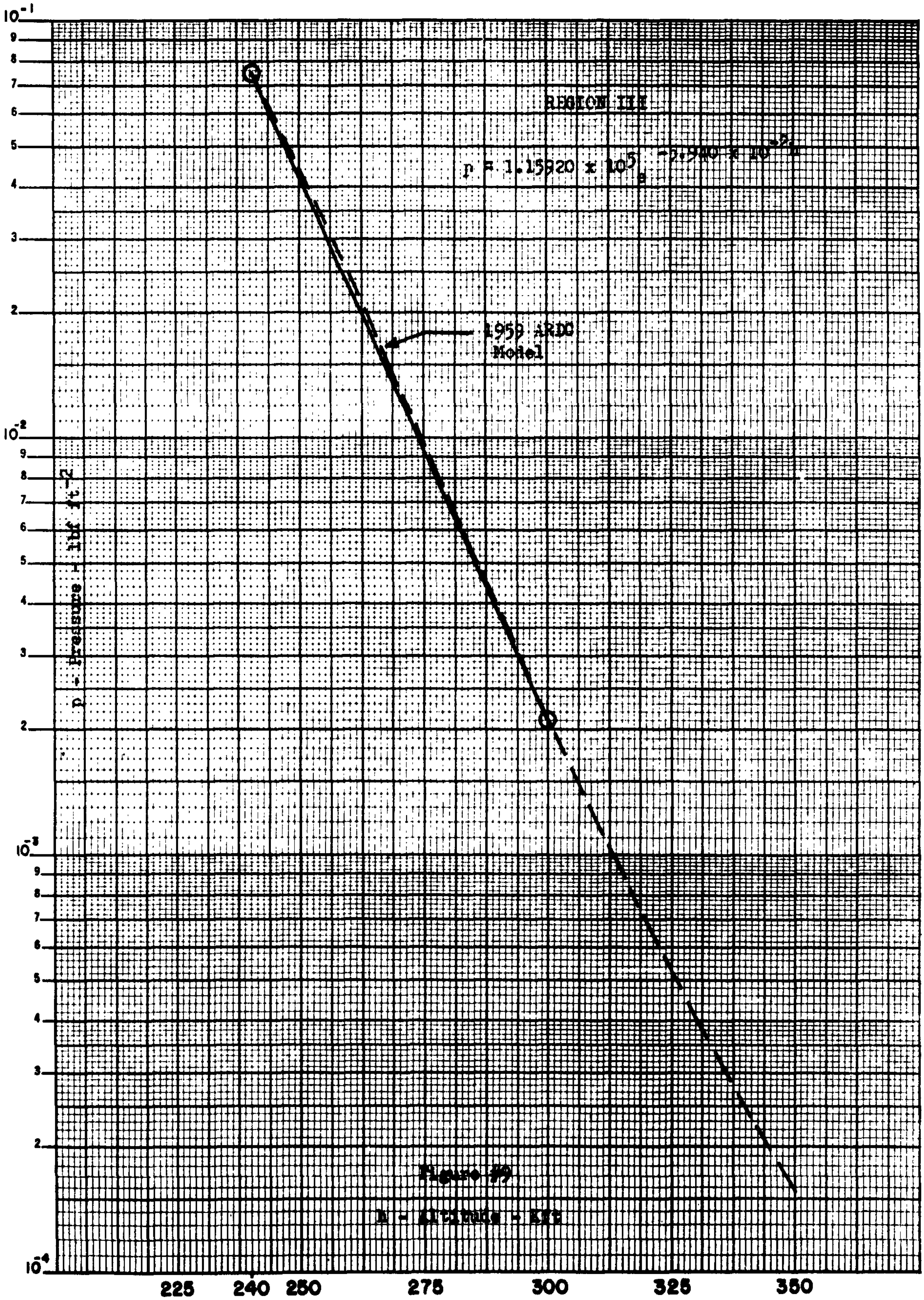
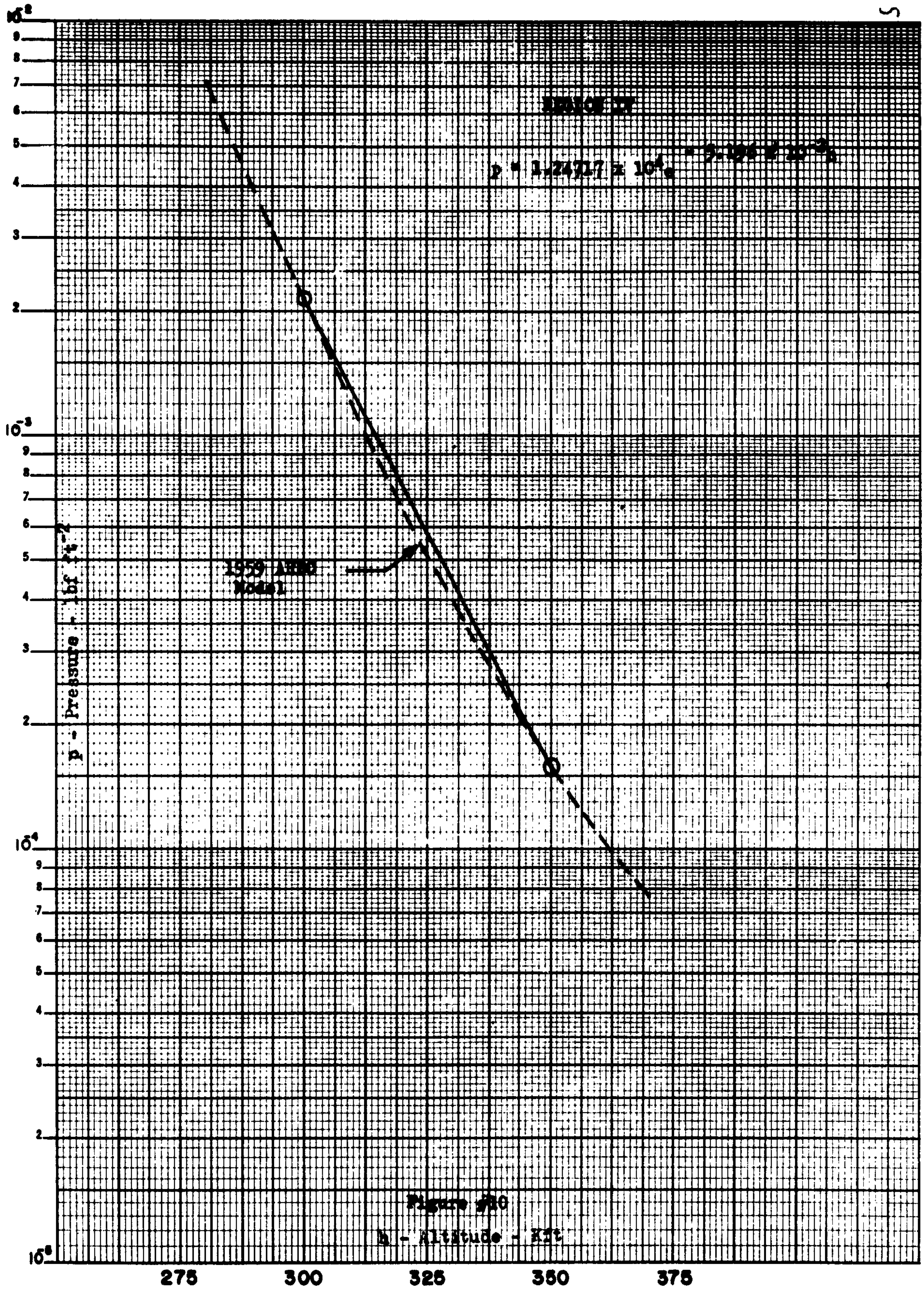

REGION III
$p = 1.15920 \times 10^5 e$
1959 ARDC Model
p - Pressure - lbf ft-2
h - Altitude - Kft
10-1
10-2
10-3
10-4
225
240
250
275
300
325
350

Figure #9



1959 ARDC Model
p - Pressure - lbf ft-2
h - Altitude - Kft
275
300
325
350
375

REFERENCES:

1. Allen, H. Julian, and Eggers, A. J., Jr., "A Study of the Motion Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds," NACA RM A53D28 - 1952.

2. Diehl, Walter, "Standard Atmosphere - Tables and Data," NACA #218 - 1925.

3. Warfield, Calvin N., "Tentative Tables for the Properties of the Upper Atmosphere," NACA TN 1200 - 1947.

4. Champion, K. W., Minzner, R. A., and Pond, H., "The 1959 ARDC Model Atmosphere," Air Force Surveys in Geophysics, No. 115-1959.

SYMBOL	DEFINITION	UNITS
h	Altitude	Kft.
p	Pressure	lbf/ft^2
ρ	Density	$slugs/ft^3$
ρ_c	Parameter	
η	Parameter	
k	Parameter	
m	Parameter	